The Intersection of Electronics, Design, and Programming

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971 SPARTAN ROBOTICS

Introduction

- I’ve been involved with hardware+software+electrical on 971 for 4 years as a student and 3 as a mentor
- Various resources for individual areas, but not so much for the combination
- To me, the individual subsystems don’t have much meaning or purpose in a robot without the others
- 971 (semi-)deliberately pushes what’s possible with FRC robots
  - Tightly coupled systems like 2014 claws, 2015 elevators+arms, 2016 unfolding, 2017 turret
  - Partly happens due to getting distracted and missing the simple solution

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Overview

- Some crazy things you can do
  - Going to refer back to these throughout
- Sensors
- Mechanical
- Motors

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Tricky things

Holding a game piece with independent jaws

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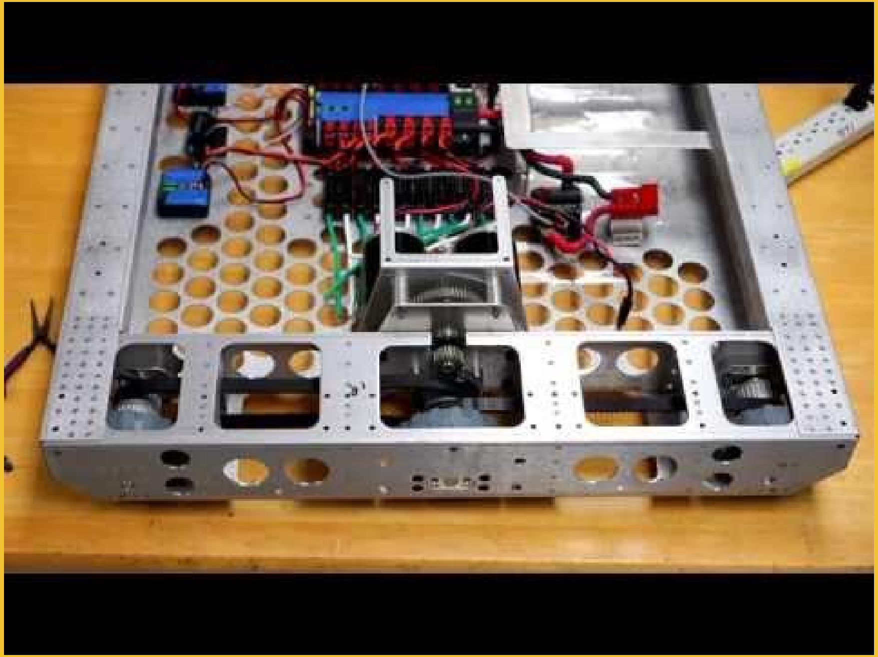
Tricky things

Moving a stack horizontally with pivoting arms



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Tricky things

Unfolding a double-jointed arm in sync without colliding with itself

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Tricky things

Shooting straight with a shooter mounted to the indexer

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Sensors

- Most obvious place for hardware+software to interact
- Give software information about what's happening
- Going to focus on robot-internal sensors (not cameras etc)
  - Drivetrain encoders are in. Generally model information from those as saying where the robot is on a flat, obstacle-free floor rather than about what's actually around the robot
- Two relevant types: binary and rotary

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Binary sensors

- On or off (aka boolean)
- Single digital input
- Easy to read
- Hall effects and switches common examples
- Switches: get triggered by acceleration
    - Some come in the KOP, many other shapes
    - 971 hasn’t used since 2012 due to bumps
- Hall effect: magnet and a sensor
    - WCP-0971 is a convenient package

Rotary sensors

- Detect rotational position
- Absolute: know the position immediately
- Incremental: only know position relative to startup (usually need to zero, coming later)
- Limited range: 1-turn, 3-turn, etc (arms, hoods)
- Unlimited range: way too many turns to count (drivetrain, shooter wheels)
- Encoders: good precision, low noise, quick response
- Potentiometer: absolute, simple, noisy

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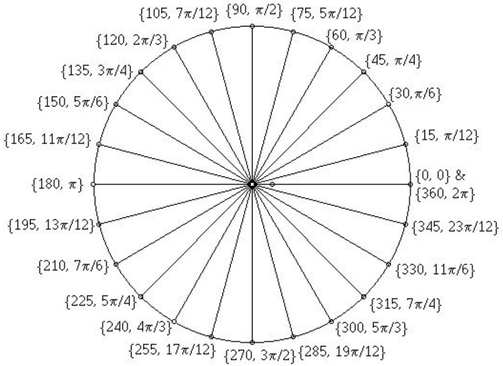
Units

- Both one of the most important things to think about and completely irrelevant
- Easy for code to deal with pretty much anything
    - As long as you keep track of it well
- Common to work in many units for the same quantity (radians, degrees, cycles, ticks), which makes it important to specify which one
- Make sure the mechanical and software teams agree on which units they're talking about



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Zeroing

- If you have an incremental encoder and want to know where the robot actually is, you have to do something
- Binary sensor at one point in the range of motion
  - Or more if you want to be fancy
- Have a potentiometer on the same mechanism
  - Sample it while everything's stationary at the start
- Encoder index pin
  - Typically more than one rotation, so still need to know which one

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Zeroing in action

Robot moves both joints over hall effect sensors

Zeroing in action

Robot moves each arm over a hall effect sensor at the start of teleop

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Precise software control

- Getting a mechanism to the place you want quickly and consistently takes both hardware and software
- Advanced software gets improvements, but a basic PID loop can get pretty far
- Mechanical matters more than people think
- Backlash is how much one connected thing moves without the other one
  - Motor to sensor
  - Motor to end effector
  - End effector to sensor
- Rigidity is how much things bend

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Backlash

- Gears, chains, bolts, everything
- Motor ends up chattering back and forth if there's backlash there
- Backlash between the encoder and other things means you can't tell where the end effector is, so you can't make it go where you want
- Really hard to do anything about in software
- Up more reductions matters less

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Rigidity

- Floppy things are hard to get where you want
- Software ends up wiggling one end back and forth, and the whole thing just flexes and doesn't go anywhere
- Think about it when designing the mechanical
- Stiffness often goes along with strength, but different materials have different properties so keep it in mind

Gear ratios

- If you're putting a lot of power through a motor all the time, it's going to get hot
- Think about holding power in addition to force
- Having extra force available lets you move it faster, and you can always limit it in software later
- More gear stages often lead to backlash though
- Think about extra friction created

Motors and controllers

- Some motors and controllers have more finesse than others
  - But also think about how much power you need
- Don’t use “brake mode”
- Motors with more cogging are harder to do fine control with
- Controllers that switch slowly are hard to work with

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Takeaways

- Think about what's going to work well for software when doing mechanical and electrical
- Making everything fit well does matter
- Pick sensors deliberately
- Think about how simple you can make it first

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Thank You!

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Bonus slides

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Encoders

- In FRC, generally means some kind of digital output
- Quadrature output (most common): incremental, easy to hook up, fast response, 2 signals
- Pulse width output: absolute, harder to read, slower/variable response time, 1 signal
- SPI/I2C (uncommon): something else with brains in the middle

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Potentiometers

- Analog (continuously varying)
- Tend to be a lot noisier than encoders
- Hard to sample quickly (especially after filtering to get rid of noise)
- Fixed number of turns (1, 3, 5, 10 are common)

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